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Geo-Positioning Selection Guide

a reference to select systems and techniques for obtaining and mapping natural resources or cultural data

U.S. Department of the Interior
Bureau of Land Management

How To Use This Selection Guide

The purpose of this guide is to assist in selecting the best, most economical mapping tools or techniques for locating natural or cultural features and their geographic coordinates. The guide is not all inclusive; only major technologies used in natural resource land management activities are covered. The tools and techniques are compared on the basis of application, accuracy, cost, and other characteristics. Applications are divided into three major groups based on scale, size of area, and amount of detail needed. Accuracies are estimated based on BLM's experience and reasonable use of each technology, and are given in metric measurements for easy comparison. Costs are divided into five relative classes with class 1 being the most costly for mapping per hectare. Each technology is color coded for cross-referencing with a description of its associated discipline at the bottom of the guide.

Aerial Photography, Photogrammetry, & Orthophotography

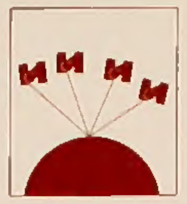
Aerial photos, because of their vertical perspective and stereo images, can assist in identifying and mapping cultural and natural features. However, while aerial photos provide easy reference to ground locations in the field, they contain distortions, and therefore, any data collected must be transferred to maps or orthophotos, or used in a photogrammetric stereoplotter to obtain geographic coordinates. Aerial photos are normally used for site-specific and medium-scale resource applications.

Photogrammetry systems require aerial photography or digital images, ground control measurements, and optical or digital equipment to collect information for 2D or 3D maps and digital data bases. Accuracy is dependent upon scale and resolution of the aerial photography and ground control. Photogrammetry is best used in mapping larger areas at great detail, such as in large-scale engineering design maps with 2-foot or less elevation contours, and is the primary tool used to produce the 7.5-minute topographic map series of the United States. Photogrammetry is evolving from the use of large, expensive optical stereoplotters to digital analysis of scanned aerial images using computer workstations. All data from photogrammetry can be directly collected in digital format. Orthophotography and digital elevation models (DEMs) are produced using photogrammetry.

Orthophotographs, orthophotoquads, and orthophotomaps are aerial photos with distortions and displacements removed using special optical or digital equipment and software with ground control measurements and elevation data. Orthophotos have most of the visual benefits of aerial photos, plus the positional accuracy of a map. They are produced to a base datum and referenced to geographic coordinates. Field data can be visually transferred to orthophotos and then digitized into a Geographic Information System (GIS). Orthophotos can be produced as large-scale project base maps for engineering and landscape design, and as 7.5-minute, 1:24,000-scale companion products to USGS topographic maps. In addition, satellite images from SPOT or Landsat can be processed into hard-copy or digital orthophotos. The newest orthophotos are produced as digital images for computer use. Once an orthophoto is produced, it can be easily updated using new aerial photography.

Aerial Video with GPS - Video systems can be mounted in aircraft and flown for near real time imaging and interpretation, but they have limited geo-positioning capability due to the inability to remove distortions from the analog video image. Video cannot be used for precise mapping purposes, but differential global positioning can provide geographic coordinates to enhance the video frame location. Information can be extracted from a video frame and superimposed onto orthophotos for increased positional accuracy for change monitoring, pest inventories, etc.

Satellite Positioning Systems



Satellite/global positioning technologies have evolved over the last 25 years from several land and satellite based navigation systems into the current Global Positioning System (GPS). GPS is a satellite-based triangulation system using measurements of radio wave carrier frequencies and transmitted codes to determine relative distances and geographic coordinates. GPS was developed for the military, but domestic applications are expanding rapidly. The Department of Defense (DOD) has implemented a security system called Selective Availability (SA) that limits accuracy to non-DOD users with a single GPS receiver to no worse than 100 meters 95 percent of the time. If SA is not in operation, ±15 meter accuracies can be obtained with a single GPS receiver. Civilian users have developed highly accurate application techniques using two GPS receivers with one located on a survey monument of known coordinates. Using inexpensive GPS receivers, this differential GPS technique can obtain field mapping accuracies equal to a USGS topographic map (±12.5 meters). More costly geodetic level GPS receivers and complex adjustment procedures can obtain relative line lengths to less than 10 centimeters. Differential GPS (DGPS) service is expanding and can provide real-time positions to ±10 meters using radio links between two receivers. GPS will not be fully operational until 1994, but can be used on a daily basis with careful planning. GPS is the only field mobile geo-positioning technology currently available for ground resource management activities.

ARGOS is an active radio wave system requiring a transmitter at the monitored location. ARGOS uses one moving satellite to receive continuous signals from a ground transmitter with geographic coordinates post-calculated at a ground base station. Small transmitters attached to animals are used to track wildlife in studies worldwide.

Terrestrial Positioning Systems

Traditional ground survey techniques have been used to establish the national datum frame of reference for natural resource mapping science and geo-positioning activities for the entire United States. The National Geodetic Survey has placed control monuments throughout the country which are used to determine geographic coordinates through survey ties to unknown locations. Most of the coordinates are based on the North American Datum of 1927 (NAD 27), but can be adjusted to the more precise NAD 83. This type of geo-positioning can be very accurate, but is labor intensive.

Calculated Ties to PLSS/GCDB - Calculations can be made from known coordinates to project new coordinates if distance and bearing are known between the two locations. The developing BLM Public Land Survey System/Geographic Coordinate Data Base (PLSS/GCDB) can be used to calculate coordinates of a feature from a tied survey or map compilation. Positional accuracies can range from 5 meters with recent surveys and good geodetic control to more than 500 meters with older surveys and limited control.

LORAN C is a ground based radio-navigation system used for aviation and sea navigation for the entire United States. Accuracy is limited due to system design and terrain masking of the signal, especially at ground level. LORAN C can be used for general navigation to a field site or to obtain quick coordinates of ground activity from an aircraft.

Cartographic Reference Systems

One of the most common techniques for determining geographic coordinates is to use existing maps or orthophotos for field compilation and then digitize the data into a GIS using a digital tablet or scan digitizing. Standard national map series, like the USGS 1:24,000-scale topographic quadrangles, or specially produced large-scale project base maps, can be used. Locating oneself in the field with a topo map is difficult because of limited detail, and errors can exceed 500 meters. It is more accurate to use an aerial photo, then transfer the location to the map.

Existing Digital Sources - Many geographic coordinate locations can be derived from existing digital maps or images, including:

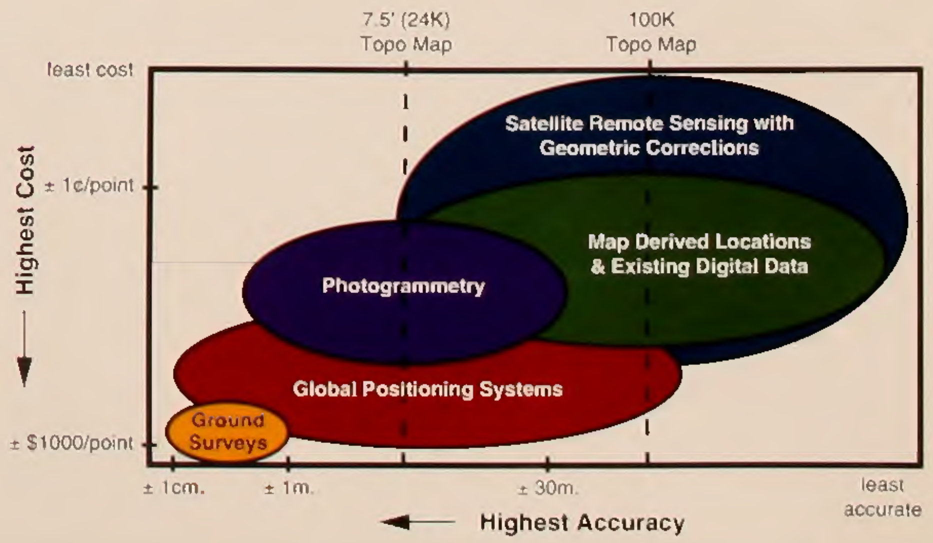
- products produced to the National Map Accuracy Standards (NMAS), such as the USGS Digital Line Graphics (DLG) 1:100,000, 30 X 60-minute and 1:24,000, 7.5-minute formats
- U.S. Census TIGER files
- Digital Elevation Models
- Digital Chart of the World (DCW)

Many State and Federal agencies have digital project data bases with geographic coordinates, but the datum, coordinate system, and map projection must be known and the accuracy and resolution checked prior to their use.

Satellite Remote Sensing Systems

Satellite imagery has the lowest cost per hectare for resource mapping and can be used for large-area resource analysis and regional applications. Since the imagery is digital, it can be transformed into an image map (orthophoto) and, when rectified, used to derive geographic positions. Automated interpretation and enhancements can be performed using digital classification and analysis software on computer workstations. Satellite imagery is becoming more available and useful at the field level due to increased microcomputer capability and greater resolution of satellite sensors.

Comparison of Relative Cost vs. Accuracy



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For more information see BLM Technical Note 389.

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Accuracy Levels	Geo-Positioning Tools	Horizontal Accuracy Estimate	Vertical Accuracy Estimate	Cost Class	Spatial Data Type				Direct Digital	Comments
					Cell Size	Point	Line	Area		
Site Specific Applications Scales Larger Than 1:12,000 Applications for valuable mineral or high visibility locations or surveying and engineering requiring the highest precision.	Survey/Geodetic GPS (Differential)	<10cm	<25cm	1		X			X	Field, developing
	Engineering Photogrammetry	±10cm	±25cm	2		X	X	X	X	Stereoplotter
	Ground Survey Ties to Geodetic Control	±10cm	±20cm	1		X				Field
Resource Applications Scales 1:12,000 to 1:25,000 Applications for medium to large areas needing more intensive accuracies and precision. Resource Base Data (RBD) should be mapped with these tools.	Resource Mapping GPS (Differential)	5-15m	±25m	3		X	X	X	X	Field, developing
	Mapping Photogrammetry	5-10m	±1-5m	3		X	X	X	X	Stereoplotter
	Digital Orthophotos (1:12,000 - 1:25,000)	5-20m	n/a	3	2-5m			X	X	Developing
	Orthophotoquad (1:12,000 - 1:25,000)	5-20m	n/a	4				X		Under construction
Scales 1:24,000 to 1:62,500 Medium scale applications for large areas requiring less intensive accuracies and precision including most resource and planning uses. Navigation point positioning and less precise location of resources can be performed with a single GPS unit.	Stereo Photo Transfer to a Topo Map	12-25m	n/a	4		X	X	X		Simple stereoplotter
	Optical Photo Transfer to a Topo Map	15-50m	n/a	5		X	X	X		Optical equipment
	Aerial Photo to Topo Map	25-75m	n/a	5		X	X	X		Field, manual
	Aerial Photo to Orthophotoquad	15-50m	n/a	5		X	X	X		Field, manual
	Field Plotting to a Topo Map	25-100m	n/a	5		X	X	X		Field, manual
	SPOT Satellite Panchromatic	10-25m	10-25m	4	10m			X	X	Terrain corrected
	Calculated Tie to PLSS GCDB	10-100m	n/a	4		X				Under construction
	Digital Line Graphic (DLG) 7.5'	12-50m	n/a	5		X	X		X	Under construction
	Digital Elevation Model (DEM) 7.5'	±15m	7-15m	5	30m				X	Vertical only
	Navigation GPS (Single GPS Unit)	35-100m	±100m	4		X			X	±15m with SA off
Regional Applications Scales Smaller Than 1:62,500 Smaller scale applications for regional areas needing less intensive or costly locations including projects covering entire districts, counties, or states. Lowest cost per ground measurement unit of coverage. Applications include unique monitoring, navigation, and less precise location of resources.	SPOT Multispectral Scanner	20-50m	n/a	4	20m			X	X	Terrain corrected
	Landsat Thematic Mapper (TM)	30-70m	n/a	4	30m			X	X	Terrain corrected
	Landsat Multispectral Scanner (MSS)	70-150m	n/a	5	80m			X	X	Terrain corrected
	LORAN C	±250m	n/a	3		X				Field
	Digital Line Graphics (DLG) - 1:100,000	±50m	10-25m	5		X	X		X	Limited contours
	TIGER Files - U.S. Census Data	±100m	n/a	5		X	X	X	X	Mixed data source
	Aerial Video With GPS	35-100m	n/a	3	varies			X		Field, distorted
	DEM (30'x60' - 1:100,000)	±50m	5-25m	5	2 arc sec.				X	Under construction
	DEM (1°x2° - 1:250,000)	±100m	±75m	5	3 arc sec.				X	Vertical only
	ARGOS Satellite Transceiver	±500m	n/a	3		X			X	Wildlife tracking
	AVHRR Weather Satellite	±1000m	n/a	5	1km				X	Daily coverage
	Digital Chart of the World - 1:1,000,000	±2000m	±650m	5		X	X	X	X	Very small scale